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A RISK ASSESSMENT MODEL FOR HEALTH SUPPLY CHAIN BASED ON HYBRID FUZZY MCDM METHOD

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This study aims to identify and evaluate the risks of the manufacturing sector in the health supply chain of the food industries. For this purpose, first, the risks related to food industry units have been identified using the fuzzy Delphi approach and then, applying the fuzzy best-worst model (F BWM) and the fuzzy decision-making trial and evaluation laboratory (F DEMATEL) model, the weights and internal relationships of criteria have been determined, respectively. For the final prioritization of the risks, a hybrid method based on F BWM and F DEMATEL has been used. To demonstrate the applicability of the proposed approach, a real case of food industry units is presented. The data are both quantitative and qualitative, and both library and field methods have been used to collect them. The results showed that among the identified factors, the biological factor had the highest priority, and the health factor had the lowest one.

Keywords: Risk Evaluation; Health Supply Chain; Food Industry; Multi-criteria Decision-Making; Fuzzy Set Theory.

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1. INTRODUCTION

One of the challenges that various industries are facing is the increased risks in organizations. These risks have significantly increased along with the growth of manufacturing and commercial processes in a way that there has always been the possibility that processes or actions do not occur as planned and, therefore, they will have undesirable results. Hence, these risks need to be considered and controlled (Spekman and Davis, 2004).

In recent years, researchers have identified and proposed various methods for assessing risks. The most widely used methods in many studies include risk probability impact matrix (RPIM), failure mode and effects analysis (FMEA), fault tree analysis (FTA), analytic hierarchy process (AHP) and analytical network process (ANP). In the RPIM method, the risks are calculated by multiplying the probability of an event by their impacts. The two criteria of "impact amount" and "probability of occurrence" of the risk are used in the form of a probability impact matrix (Usuda *et al*., 2016). One of the main drawbacks of this method is its unreliability. Another weakness of this method is that the importance of risks with a low probability of occurrence and high significant impact is ignored, and furthermore, risks with a high probability of occurrence and insignificant impact are considered to be equivalent to risks with a low probability of occurrence and significant impact (Golgeci and Ponomarov, 2013).

FMEA is another method of risk assessment, which is calculated by multiplying the three criteria of severity, detection rate, and probability of risk occurrence (Rezaee *et al*., 2018). The main drawback of this method is that the weights of the mentioned criteria are considered equal. Also, this method does not take into account the uncertainty of data (Yousefi *et al*.,

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2018). In the FTA method, the evaluation is done a priori and from top to bottom. Other common approaches of risk assessment include the multi-criteria decision-making (MCDM) methods such as AHP and ANP (Mokarram *et al*., 2022). One of the disadvantages of using these methods is that the number of identified risks must be limited. In addition, creating a comparative matrix is time-consuming and costly if there is a high number of criteria.

The health system has one of the most complex supply chains due to the existence of major risks. This system is considered a risky one because it deals with human health. In general, the health supply chain (HSC) includes the following most important scopes:

- Drug supply chain (DSC): DSC is divided into two main categories. The first category includes manufacturers, distributors (pharmacies), private clinics and patients, and the second category includes manufacturers, hospitals, hospital pharmacies, and patients (Imran, Kang and Ramzan, 2018). Figure 1 shows the different parts of DSC.

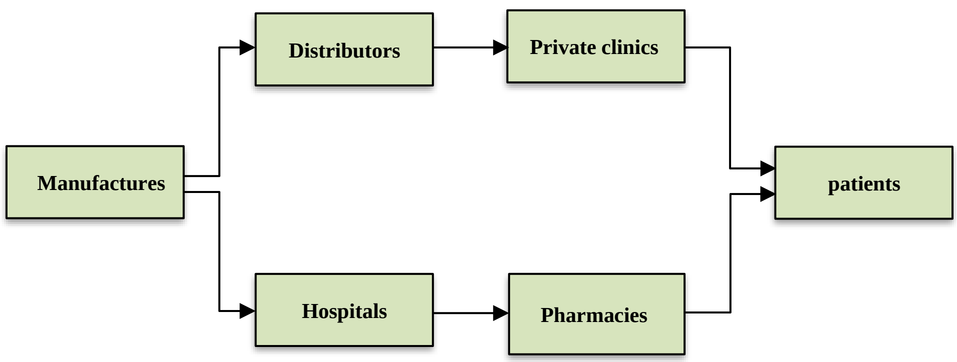

Figure 1. Different parts of DSC (Imran *et al*., 2018)

- Blood supply chain (BSC): Research in the field of BSC management was conducted in 1960 by Van Zyl (1963). It was performed on perishable products, which included blood products. BSC includes patients, hospitals, blood centers, fixed blood collection facilities, mobile blood collection facilities, and blood donors (Zahiri *et al*., 2015).
- Organ transplant supply chain (OTSC): One of the first studies on organ transplant allocation was conducted by Ruth *et al.* (1985). The OTSC network includes the donor, the recipient, hospitals, transplant centers, and transportation agents (Zahiri *et al*., 2014).
- Food supply chain (FSC): FSC has been analyzed and divided into food quality, food safety, and food waste (Esteso *et al*., 2018).

This study examines the FSC, which plays an important role in the health of citizens' lives. Foodstuffs poses the greatest challenges to FSC management. In addition, the food chain has always been one of the most important and challenging management issues due to its short life and perishable properties. Food is one of the main determinants of health or disease in society, and its supply chain, from raw materials to factories and ultimately to consumers, can all affect the general health of society, which is one of the concerns of the health system. Of course, this chain is exposed to various risks due to its inherent complexity. Identifying and managing these risks can significantly improve system performance.

An examination of the previous literature on the risk assessment methods of HSC reveals several research gaps. In these methods, the importance and impacts of risks on the whole HSC related to the food industries has been less studied. Furthermore, the previous studies and investigations have not paid attention to the interactions among risks. Intra- and extra-organizational risks of FSC have not been identified separately, and moreover, the internal and external factors of FSC have not been extensively determined. It should be noted that the risks identified in the public supply chain are not necessarily generalizable to the HSC, and this highlights the need for new research in this context. However, recognizing the risks under the mentioned conditions requires an approach that both leads to consistent comparisons and provides more reliable results and in addition, considers the structure and relationships between risks in the evaluation process.

This study identifies the risks of HSC in the food industries by using a hybrid approach and considering an uncertain environment. For this purpose, the existing risks in the manufacturing sector of FSC in the food industry units are evaluated in two stages. The whole potential risks are first identified using the field and library research methods, and then, by employing the fuzzy Delphi (F Delphi) method, the final risks are extracted. Afterward, the weights of the risks are determined by the fuzzy best-worst method (F BWM), and the internal relationships among the risks are specified by using the fuzzy DEMATEL (F DEMATEL) technique. By combining these two methods, the final weights are calculated, and next, the extracted risks are prioritized. The steps of the present study are illustrated in Figure 2.

The innovations of the present study can be summarized as follows:

- Identifying the intra- and extra-organizational risks of the FSC under an uncertain environment.
- Calculating the final weights of the risks by using a hybrid approach, so that both the external and internal weights of risks are considered.
- Prioritizing the FSC risks in order to identify the most important ones.
- Proposing an integrated model based on the F Delphi, the F BWM and the F DEMATEL methods to evaluate and rank the risks of FSC.

The remainder of this study is organized as follows. Section 2 highlights the theoretical foundations and background of the study. The materials and methods used are described in Section 3. Section 4 details the implementation procedures and the techniques of conducting the case study, and finally, the conclusions and recommendations are discussed in Section 5.

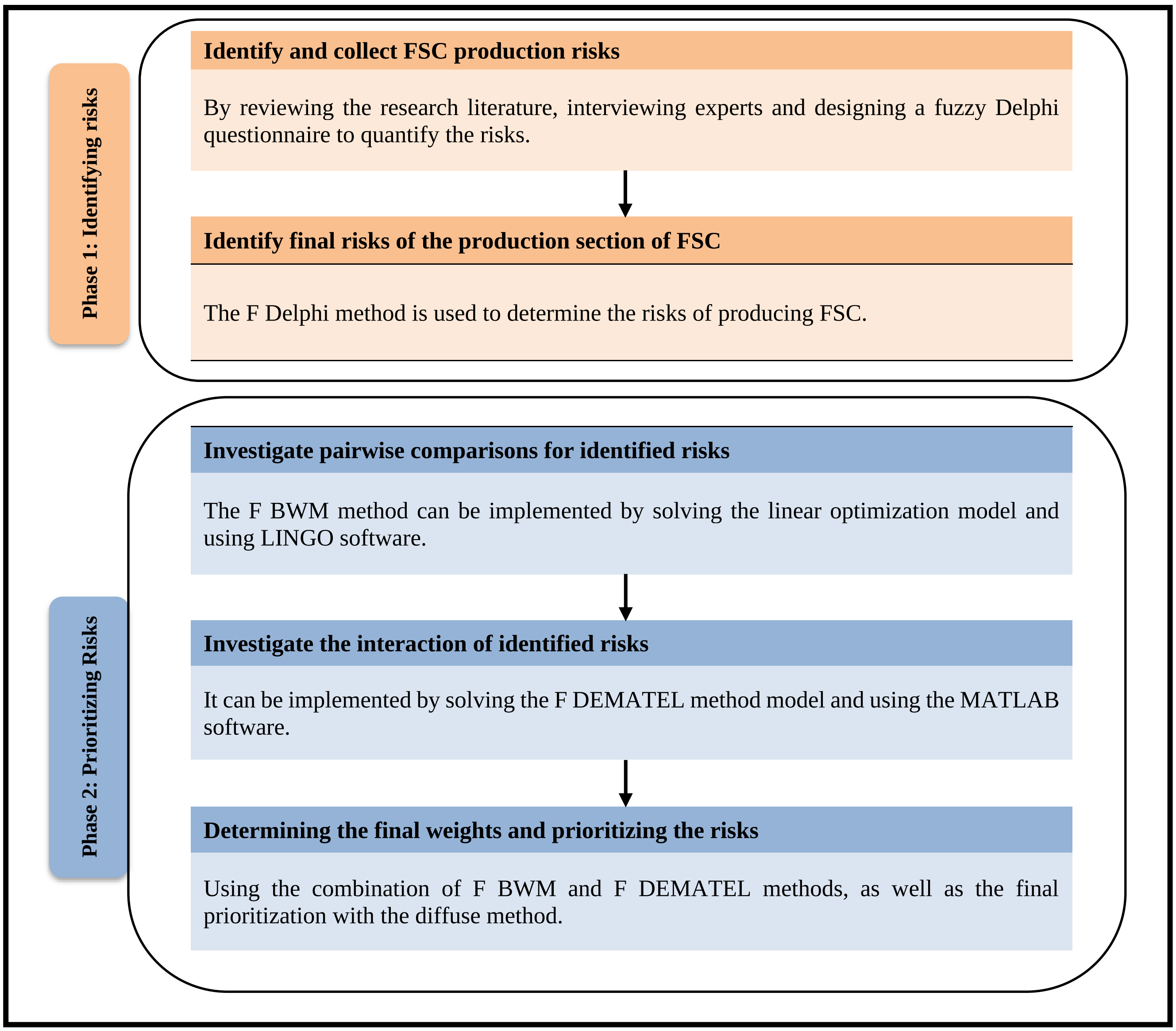

Figure 2. Conceptual framework of the present study

2. LITERATURE REVIEW

This section reviews the literatures of the study on the risk assessment methods, the supply chain risks, and the HSC risks.

2.1 Risk assessment

Sarker *et al.* (2016) considered risk management in production scheduling under uncertain conditions. They investigated task scheduling under ideal conditions and rescheduling, as well as risk analysis in a manufacturing commercial unit. to obtain the logical ranking of change modes and effects analysis (CMEA), Zhu *et al.* (2017) employed an integrated assessment method based on Shannon entropy, rough set theory, and grey set theory. In this research, the entropy weighting method was used to calculate the relative importance of risk factors. Moreover, a grey relational analysis with rough number was proposed to evaluate the risk ranking of CMEA. Pawin vivid *et al.* (2020) examined the occupational risks in the truck manufacturing industry. They identified fourteen different risks and then, ranked the risks using the risk priority number (RPN) method. Bathrinath *et al.* (2020) studied the risks of the textile industry. They conducted a case study in the textile industry of southern Tamilnadu, India. They used a hybrid MCDM method to identify the risks and then applied the TOPSIS method to rank them. In order to assess the risks of the manufacturing unit in a hydrogen production company, Li *et al.* (2020) used the hybrid DEMATEL and TOPSIS approach. The results indicated that this method was an efficient tool for managing risk assessment in the hydrogen production company. Jahangoshai Rezaee *et al*. (2020) investigated HSE risk assessment in the field of chemical industries. For this purpose, they prioritized the HSE risks by employing a hybrid method based on FMEA, fuzzy inference system and fuzzy data envelopment analysis (DEA). Lyu *et al.* (2020) investigated the risks of the metro system using the AHP and TFN-AHP methods. They declared that most subway lines were at high risk, and the percentage of risk levels determined by the TFN-AHP method was higher than the AHP method. In addition, the fuzzy AHP method was more distinct in showing the risks than the AHP method. Koohathongsumrit and Meethom (2021) proposed an integrated model based on the fuzzy risk evaluation, AHP, and DEA for route choice in multimodal transportation networks in a real case study. Pourbabagol *et al.* (2023) utilized a network DEA model to assess the agile supply chain performance of dairy firms under a fuzzy environment. They declared that this model can be used for qualitative criteria and multi-stage processes. By employing the FMEA and GRA methods, Minguito and Banluta (2023) evaluated the risks of the humanitarian supply chain. This research was carried out under the conditions of corona disease, and the findings showed that the results of both models were the same.

2.2 Supply Chain Risks

Díaz-Curbelo *et al*. (2020) investigated how to use the fuzzy set theory in different approaches of supply chain risk management in order to control uncertainty. Gupta *et al*. (2014) divided supply chain risks into internal and external parts. In their study, the internal risks were subdivided into sub-factors, including operational risk, organizational risk, and technological risk, and the external risks were subdivided into sub-factors, including environmental risk, economic risk, and political risk. Finally, they ranked the risk-related sub-factors. To select suppliers in the field of supply chain risk management, Kiani Mavi *et al*. (2016) examined nine factors related to quality, on-time delivery, and performance history. For this purpose, they used the Shannon entropy and the fuzzy TOPSIS methods to weight the criteria and rank the suppliers, respectively. By examining the approaches of risk assessment and management in the field of economy, Abdel-Basset *et al*. (2019) divided risks into two internal and external parts. To quantify supply chain risks, they employed an integrated model by combining the AHP and the neutrosophic methods. Moktadir *et al*. (2021) used the Pareto approach and BWM to identify and assess the risks in the leather industry supply chain.

2.3 Health Supply Chain Risk Assessment

Mithun *et al.* (2019) assessed the risks of FSC and pointed out the consequences of reducing food waste. To investigate the relationships and interactions among the FSC risks, they used a hybrid approach based on the grey theory and DEMATEL. Using the FMEA method, Wu and Hsiao (2020) assessed the risks involved in the quality and safety of the frozen food chain. El Mokrini *et al.* (2016) used a fuzzy hybrid AHP-PROMETHEE approach to address the various risks of DSC under uncertain environment. They classified eighteen types of risks into six main factors, including storage and distribution processes, finance, technology, information, relations, and internal criteria of the organization. Grida *et al.* (2020) examined the impact of COVID-19 prevention policies on three scopes of the FSC, including supply, demand, and logistics. For this purpose, they utilized BWM and TOPSIS under plithogenic conditions.

The reviewed studies on the risks of HSC are summarized in Table 1. As shown in Table 1, the identification, assessment and ranking of HSC risks in the context of drug, blood, transplantation and food have been examined. Various methods have been used for this purpose. Some of the challenges that today, FSC decision makers attempt to identify and manage them are as follows:

- What are the intra- and extra- organizational risks affecting FSCs?
- What factors and cases do each of these internal and external organizational risks include?
- How are these risks interconnected?
- How is the final prioritization of these risks under conditions of uncertainty?

It is noteworthy that in the previous research, the studies on the interactions among criteria and the uncertainty issue in the FSC have been less studied. In addition, as far as the researchers have investigated, there has been no study in which the calculation of the final weight of risks is determined by an integrated approach that considers both the external and internal weight of risks in the HSC under uncertain environment. In this study, in order to identify, prioritize and obtain the absolute weight of risks, F BWM method and F DEMATEL method have been employed, respectively. Both methods have been used under uncertainty conditions. It should be noted that most of the research variables are expressed qualitatively and lingual. To measure and analyze these variables in a fuzzy environment, it is better to convert them to crisp numbers. For this purpose, F BWM technique is employed. In the stage of evaluating and allocating different weights, this technique is simpler and more precise than others. Therefore, the criteria ranking is done more accurately. The approach presented in this study is able to calculate the final weights of the risks by considering both their external and internal weights in the uncertain FSC. Finally, a real case study related to units of food industries in Golestan province, Iran, has been applied to evaluate the efficacy of the proposed hybrid approach.

Table 1. Reviewed studies and compare them with the current paper

References	**Method Used**	**Fuzzy**	**Risk Assessment**	**Supply Chain**					**Internal Relationships**
				Drug	**Blood**	**Organ Transplant**	**FOOD**	**Other**	
Hamdan and Diabat (2020)	Robust optimization		✓		✓				
Wongnak *et al*. (2020)	Microbiological		✓				✓		
Korucuk *et al*. (2023)	BN-SWARA, BN-TOPSIS							✓	
Li *et al*. (2022)	DEMATEL-ISM and CM-TOPSIS	✓	✓					✓	
Shafiee *et al*. (2022)	Fuzzy DEMATEL	✓	✓				✓		
Valipour *et al*. (2022)	FCM, FMEA, FBWM	✓	✓						
Yazdani *et al*. (2022)	BWM, Fuzzy MARCOS	✓					✓		
Jiang *et al*. (2018)	SCOR–F AHP	✓	✓					✓	
McDaid *et al*. (2023)	BWM-FIS	✓					✓		
Wang *et al*. (2012)	F AHP	✓	✓					✓	
de Curs *et al*. (2020)	Fuzzy AHP	✓	✓					✓	
Wan *et al*. (2019)	Fuzzy Bayesian-based FMEA	✓	✓					✓	
Ahmed *et al*. (2023)	FAHP, FIS	✓	✓						
Rajesh and Ravi (2015)	Grey–DEMATEL approach	✓	✓					✓	✓
Koohathongsumrit and Chankham (2023)	MARCOS, BWM	✓	✓					✓	
Khan *et al*. (2023)	AHP		✓					✓	
Gamal *et al*. (2022)	ANP, MARCOS	✓		✓					
Gómez and España (2020)	QFD	✓	✓	✓					
Nahavandi and Tavakoli (2022)	FMEA, TOPSIS	✓	✓					✓	
Raihan *et al*. (2022)	F AHP, FCEM	✓	✓				✓		
Han *et al*. (2016)	PTDM		✓			✓			
Verma *et al*. (2022)	SLR, AHP		✓					✓	

References	Method Used	Fuzzy	Risk Assessment	Supply Chain					Internal Relationships
				Drug	Blood	Organ Transplant	FOOD	Other	
Song and Zhuang (2017)	GUMUF		✓				✓		
Paul *et al*. (2020)	BBN		✓	✓					
Dagsuyu *et al*. (2021)	FMEA, AHP		✓					✓	
Alshehri *et al*. (2022)	F AHP, F WASPAS		✓					✓	
Jafarzadeh Ghoushchi *et al*. (2022)	BWM, COPRAS	✓	✓					✓	
Brosas *et al*. (2017)	Input-output mode	✓	✓					✓	
Karadayi-Usta and SerdarAsan (2021)	ISM, MICMAC		✓					✓	
Gul and Ak (2020)	BWM, MAIRCA	✓	✓					✓	
Current Paper	F Delphi - F BWM - F DEMATEL	✓	✓				✓		✓

3. MATERIALS AND METHODS

3.1 Identifying and Collecting Supply Chain Risks

In the present study, field and library methods were used to collect data, in order to identify and evaluate FSC risks, a qualitative research method was employed, and to analyze the situation and measure the identified risks, a quantitative research method was used. In the qualitative part, data extraction was conducted based on the literature and interviews using the F Delphi questionnaire. In the quantitative part, the F Delphi technique was utilized to identify the initial risks.

3.2 Identifying Risks Using The F Delphi

In the second part of the present study, interviews and questionnaires were used to collect data, and then, effective criteria for assessment of the FSC risks have been identified using the F Delphi method among industry experts of Small Industries and Industrial Parks Organization (ISIPO) of Golestan province, Iran. Moreover, triangular fuzzy numbers (TFNs) were used, according to Table 2, to convert the words of experts' linguistic variables into fuzzy numbers.

Next, the value of the TFN of each criterion scored by the experts was calculated. To find out the experts' opinions, the geometric mean method was used. The value of the criterion j from the point of view of expert i is denoted by $W_{ij} = (l_{ij}, m_{ij}, u_{ij})$, whose values, respectively from left to right, are the smallest possible value, the most possible value and the largest possible value of the TFN. The fuzzy value of each criterion is calculated according to Equation (1):

$$l_j = min(l_{ij}), m_j = \frac{1}{n}\sum_{i=1}^{n} m_{ij}, u_j = \max(u_{ij}) \tag{1}$$

Table 2. Linguistic variables and corresponding fuzzy numbers used in the F Delphi method (Haghshenas *et al*., 2017)

Linguistic variable	Fuzzy number
Very Low (VL)	(0,0,1)
Low (L)	(0,0.1,0.3)
Medium Low (ML)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium-High (MH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1)
Very High (VH)	(0.9,1,1)

Where *n* is the number of experts. In the next step, the above-mentioned fuzzy value must be defuzzified by using Equation (2):

$$s_j = \frac{l_j + 4m_j + u_j}{6} \tag{2}$$

By considering s_j values, criteria with values higher than 0.7 are approved, and consequently, the other criteria are deleted (C. H. Wu and Fang, 2011).

3.3 Weighing the Criteria Using F BWM

Based on the BWM proposed by Rezaei (2015), the criteria are determined by the decision-maker, and pairwise comparisons are performed among the criteria. Then, a maximum-minimum problem is formulated and solved to determine the weights of the various criteria. The F BWM was first proposed by Guo and Zhao (2017). Its algorithm is similar to BWM. Considering the respondents' linguistic terms, the use of fuzzy numbers leads to more accuracy and better results in calculations.

Table 3. Linguistic variables and associated TFNs (Guo and Zhao, 2017)

Linguistic Variable	Fuzzy numbers
Equal Importance (EI)	(1,1,1)
Weak Importance (FI)	$(\frac{2}{3}, 1, \frac{3}{2})$
Fairly important (FI)	$(\frac{3}{2}, 2, \frac{5}{2})$
Very important (VI)	$(\frac{5}{2}, 3, \frac{7}{2})$
Altogether Importance (AI)	$(\frac{7}{2}, 4, \frac{9}{2})$

Assume that there are *n* criteria. Pairwise comparisons of these *n* criteria are performed through existing linguistic variables. In other words, according to Table 3, the respondents' linguistic variables are converted into corresponding TFNs. The steps of the F BWM are as follows:

Step 1) *Determining a set of criteria for decision making*:
The set of criteria is defined as $\{c_1, c_2, \ldots, c_n\}$ that is needed to make a decision.

Step 2) *Determining the best (the most important and the most desirable) and the worst (the least important and the least desirable) criteria*:
The decision-maker generally determines the best and the worst criteria and no comparisons are made at this stage.

Step 3) *Determining the preference of the best fuzzy criterion over all other criteria*:
The preference vector of the best fuzzy criterion over other criteria is displayed as $\tilde{A}_B = (\tilde{a}_{B1}, \tilde{a}_{B2}, \ldots, \tilde{a}_{Bn})$. In this vector, $\tilde{a}_{Bj}$ indicates the preference of criterion *B* over criterion *j*, and also, $\tilde{a}_{BB}$ = (1,1,1).

Step 4) *Determining the preference of all criteria over the worst fuzzy criterion*:
The preference vector of the other criteria over the worst case is displayed as $\tilde{A}_w = (\tilde{a}_{w1}, \tilde{a}_{w2}, \ldots, \tilde{a}_{wn})$. In this vector, $\tilde{a}_{jw}$ represents the preference of criterion *j* over the worst criterion *w* and also, $\tilde{a}_{ww}$ = (1,1,1).

Step 5) *Determining the optimal fuzzy weight* $\left(\tilde{W}_1^*, \tilde{W}_2^*, \ldots, \tilde{W}_n^*\right)$:
For determining the optimal weight of each criterion, the pairs of a $\tilde{a}_{Bj} = \frac{\tilde{W}_B}{\tilde{W}_j}$ and $\tilde{a}_{jw} = \frac{\tilde{W}_j}{\tilde{W}_w}$ are formed; Then, for satisfying these conditions for all *j*'s, a solution must be found so that the two expressions $\left|\frac{\tilde{W}_B}{\tilde{W}_j} - \tilde{a}_{Bj}\right|$ and $\left|\frac{\tilde{W}_j}{\tilde{W}_w} - \tilde{a}_{jw}\right|$ are maximized for all *j*'s that have been minimized. The optimization problem for determining the optimal fuzzy weight $\left(\tilde{W}_1^*, \tilde{W}_2^*, \ldots, \tilde{W}_n^*\right)$ is presented as the model (3).

$$Min \ \underset{j}{\text{Max}}\left\{\left|\frac{\widetilde{W}_B}{\widetilde{W}_j}-\ \tilde{a}_{Bj}\right| \ \text{و} \ \left|\frac{\widetilde{W}_j}{\widetilde{W}_w}-\ \tilde{a}_{jw}\right|\right\}$$
$$\text{s.t}\begin{cases}\sum_{\mathrm{j=1}}^{\mathrm{n}} R\left(\widetilde{W}\right)_j = 1\\ l_j^w \le m_j^w \le u_j^w\\ l_j^w \ge 0\\ j = 1,2,\ldots,n\end{cases} \tag{3}$$

where $\widetilde{W}_B = (l_B^w, m_B^w, u_B^w)$, $\widetilde{W}_j = \left(l_j^w, m_j^w, u_j^w\right)$, $\widetilde{W}_w = (l_W^w, m_W^w, u_W^w)$, $\tilde{a}_{Bj} = \left(l_{Bj}, m_{Bj}, u_{Bj}\right)$, and $\tilde{a}_{jw} = \left(l_{jw}, m_{jw}, u_{jw}\right)$. Next, the model (3) converts into an optimization problem with the nonlinear constraints (4).

$$\xi \ \text{Min}$$
$$\text{s.t}\begin{cases}\left|\frac{\widetilde{W}_B}{\widetilde{W}_j}-\ \tilde{a}_{Bj}\right| \ll \ \tilde{\xi}\\ \left|\frac{\widetilde{W}_j}{\widetilde{W}_w}-\ \tilde{a}_{jw}\right| \ll \ \tilde{\xi}\\ \sum_{j=1}^{n} R(\widetilde{W}_j) = 1\\ l_j^w \le m_j^w \le u_j^w\\ l_j^w \ge 0,\\ j = 1,2,\ldots,n\end{cases} \tag{4}$$

In the model (4), $\tilde{\xi} = \left(l^{\xi}, m^{\xi}, u^{\xi}\right)$. Considering $l^{\xi} \le m^{\xi} \le u^{\xi}$, $\tilde{\xi}^* = (k^*, k^*, k^*)$ and $k^* \le l^{\xi}$, the final model (4) converts into the model (5).

$$\tilde{\xi}^* \ \text{Min}$$
$$\text{s.t}\begin{cases}\left|\frac{(l_B^w, m_B^w, u_B^w)}{\left(l_j^w, m_j^w, u_j^w\right)}-\ \left(l_{Bj}, m_{Bj}, u_{Bj}\right)\right| \ll \ (k^*, k^*, k^*)\\ \left|\frac{\left(l_j^w, m_j^w, u_j^w\right)}{(l_W^w, m_W^w, u_W^w)}-\ \left(l_{jw}, m_{jw}, u_{jw}\right)\right| \ll \ (k^*, k^*, k^*)\\ \sum_{j=1}^{n} R\left(\widetilde{W}\right)_j = 1\\ l_j^w \le m_j^w \le u_j^w\\ l_j^w \ge 0\\ j = 1,2,\ldots,n\end{cases} \tag{5}$$

By solving the model (5), the optimal fuzzy weight $\left(\widetilde{W}_1^*, \widetilde{W}_2^*, \ldots, \widetilde{W}_n^*\right)$ is obtained.

3.4 Calculating The Internal Relations Among Criteria Using F DEMATEL

F DEMATEL method, using fuzzy language variables, facilitates the decision-making process under uncertain conditions. The steps of this technique are as follows:

Step 1) *Creating the direct relations matrix*:
In this step, the initial survey matrix is created in such a way that the rows and columns of this matrix are the criteria of the decision-making problem.

Step 2) *Designing the fuzzy linguistic criteria*:
Linguistic variables are expressed by fuzzy sets, and each of those is expressed by a membership function. In this study, the five-point Likert scale was used to convert linguistic variables into fuzzy numbers, which is shown in Table 4.

Table 4. Fuzzy Language Scale (Ataei, 2010)

Linguistic Variable	Fuzzy Number
Very high influence	(0.7,0.9,1)
High influence	(0.5,0.7,0.9)
Low influence	(0.3,0.5,0.7)
Very low influence	(0.1,0.3,0.5)
No influence	(0,0.1,0.3)

Step 3) *Constructing the initial decision-making matrix* $(\tilde{o})$:
In this step, each respondent is asked to determine the effect of each criterion on the other criterion based on Table 4. $\tilde{o}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ shows the respondent's opinion about the effect of criterion *i* on criterion *j*. For each respondent, a matrix $n \times n$ that must have fuzzy properties is defined as $\tilde{o}^p = [\tilde{o}^p_{ij}]$. *P* stands for the respondents and *n* indicates the number of factors studied (Liou, Yen and Tzeng, 2008).

$$\tilde{o}_{ij} = \frac{1}{P} \times \sum_{p=1}^{p} \tilde{a}_{ij} \tag{6}$$

Initial decision-making matrix $\tilde{o}$ (7) is simply derived from the mean of all respondents' opinions, in a way that $\tilde{o}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is TFN.

$$\tilde{o} = \begin{bmatrix} \tilde{o}_{11} & \tilde{o}_{12} & \cdots & \tilde{o}_{1n} \\ \tilde{o}_{21} & \tilde{o}_{22} & \dots & \tilde{o}_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \tilde{o}_{m1} & \tilde{o}_{m2} & \cdots & \tilde{o}_{mn} \end{bmatrix} \tag{7}$$

Step 4) *Calculating the normalized matrix* $(\tilde{Z})$:
Equation (8) is used to obtain the normalized matrix (*Z*).

$$\tilde{Z} = K \times \tilde{O} \tag{8}$$

in a way that

$$K = min\left[\frac{1}{\max\limits_{1 \ll j \ll n} \sum_{j=1}^{n} |\tilde{o}_{ij}|}, \frac{1}{\max\limits_{1 \ll i \ll n} \sum_{i=1}^{n} |\tilde{o}_{ij}|}\right]$$

The normalized matrix obtained from Equation (8) is indicated by matrix (9) as:

$$\tilde{Z} = \begin{bmatrix} \tilde{Z}_{11} & \tilde{Z}_{12} & \cdots & \tilde{Z}_{1n} \\ \tilde{Z}_{21} & \tilde{Z}_{22} & \dots & \tilde{Z}_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \tilde{Z}_{m1} & \tilde{Z}_{m2} & \cdots & \tilde{Z}_{mn} \end{bmatrix} \tag{9}$$

Step 5) *Calculating the fuzzy limit matrix* $(\tilde{V})$:
In this step, the matrix $\tilde{V}$ for each fuzzy limit $(l''_{ij}, m''_{ij}, u''_{ij})$ is calculated by Equation (10).

$$l''_{ij} = \tilde{Z}_l \times (I - \tilde{Z}_l)^{-1}, m''_{ij} = \tilde{Z}_m \times (I - \tilde{Z}_m)^{-1}, u''_{ij} = \tilde{Z}_u \times (I - \tilde{Z}_u)^{-1} \tag{10}$$

Then, the lower, middle and upper limits TFN are combined together to form the matrix $\tilde{V}$ (11).

$$\tilde{V} = \begin{bmatrix} \tilde{V}_{11} & \tilde{V}_{12} & \cdots & \tilde{V}_{1n} \\ \tilde{V}_{21} & \tilde{V}_{22} & \dots & \tilde{V}_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \tilde{V}_{m1} & \tilde{V}_{m2} & \cdots & \tilde{V}_{mn} \end{bmatrix} \tag{11}$$

Step 6) *Formation of Matrix V:*
Each $\tilde{V}_{ij}$ of the matrix, *V* is converted to a crisp number using Equation (12). As a result, the matrix *V* is created.

$$V= \frac{(l+4m+u)}{6}\ V= \tag{12}$$

Step 7) *Calculating the values of $D_i - R_i$ and $D_i + R_i$:*
where D_i and R_i are the sum of each row and column of the matrix *V*, respectively.

4. FINDINGS OF THE STUDY

4.1 Identification of Risks Through F Delphi

The statistical population of this study is composed of the units of food industries in Golestan province, Iran. The food industries experts' and managers' opinions were collected. To design the questionnaire, at first, based on the literature, 70 types of risks were identified. Based on the Delphi method, some experts introduced new risks that did not get the necessary points by other experts in the scoring section and, therefore, were eliminated. The identified risks are shown in Table 5.

Table 5. Identified risks

Sources	Identified factors and indices
Chopra and Sodhi (2004); (Pan and Cai, 2008)	Suppliers
(Chopra and Sodhi, 2004); (Pan and Cai, 2008)	Manufacturers
(Chopra and Sodhi, 2004)	Distributors
(Matzler, Grabner-Kräuter and Bidmon, 2008); (Gordon, McKeage and Fox, 1998)	Consumers
(Zsidisin, Ellram, Carter and Cavinato, 2004)	Sanitation and Health
(Bakhtiyari, Khodadad and Barati, 2015); (Karami, 2000)	Biologically
(Pan and Cai, 2008); (Badea, Prostean, Goncalves and Allaoui, 2014)	Political
(Sofyalıoğlu and Kartal, 2012)	Economic
(Pan and Cai, 2008)	Technology
(Chopra and Sodhi, 2004); (Pan and Cai, 2008)	Environmental
(Chopra and Sodhi, 2004)	High cost of transportation
(Chopra and Sodhi, 2004)	Inability to meet demands
(Chopra and Sodhi, 2004)	Timely supply of raw materials
(Ekhtiari, 2010); (Michalak and Uhde, 2012)	Increasing interest rates of banks and institutions
(Chopra and Sodhi, 2004)	Lack of production quality
(Badea *et al*., 2014)	Failure to send on time
(Ismal, 2010)	Lack of liquidity
(Feriozzi, 2011); (Nickell, 1996); (Baggs and De Bettignies, 2007)	High level of competition
(Berument and Taşçı, 2002)	Liberalization of energy carrier prices
(Chopra and Sodhi, 2004)	Wrong production schedule
(Grullon and Michaely, 2014)	Unhealthy competition
(Trkman and McCormack, 2009); (Olson and Dash Wu, 2010)	Rising cost of the product
(Zhang, 2008)	Lack of experienced technical staff in the province
(Zhang, 2008)	Stop production
(Zhang, 2008)	Incorrect forecast of demand
(Sofyalıoğlu and Kartal, 2012)	Human resource risk

Sources	Identified factors and indices
(Sofyalıoğlu and Kartal, 2012)	Loss of key personnel
(Sofyalıoğlu and Kartal, 2012)	Machine and equipment failure
(Chopra and Sodhi, 2004)	Product return by the customer
(Chopra and Sodhi, 2004)	Receive arrears
(Chopra and Sodhi, 2004)	Increase the price of the final product
(Cooper and Chapman, 1987)	Decreased purchasing power of different segments of the population
(Jia and Rutherford, 2010)	Cultural differences
(Aksoy, Erdem and DinÇol, 1974); (Yimrungruang, Cheevaporn, Boonphakdee, Watchalayann and Helander, 2008)	Risk of respiration of chemical particles, dust and gases from machinery in the workplace
(Macfarlane *et al*., 1997)	Stand for a long time
(Falaki, Akbari, Derakhshan, Hannani and Motalebi Kashani, 2016)	Carrying more than the load capacity by the worker
(Harris *et al*., 2012); (Janwantanakul, Pensri, Moolkay and Jiamjarasrangsi, 2011)	Use of stimulants and caffeine by the worker
(Falaki *et al*., 2016)	Improper handling of cargo by the worker
(Janwantanakul *et al*., 2011)	Prolonged sitting and repetitive work
(Busch-Vishniac *et al*., 2005)	Existence of a lot of noise in the workplace
(Ebrahimnejad, Mousavi and Mojtahedi, 2008); (Goh, Lim and Meng, 2007)	Malta fever
(Ebrahimnejad *et al*., 2008); (Goh *et al*., 2007)	Prevalence of Quaid disease 19
(Ebrahimnejad *et al*., 2008); (Goh *et al*., 2007)	Smallpox
(Cooper and Chapman, 1987); (Ebrahimnejad *et al*., 2008)	Strikes
(Ebrahimnejad *et al*., 2008)	International relations of the country
(Harstad and Svensson, 2011)	Existence of lobbying in the field of production
(Chopra and Sodhi, 2004); (Cooper and Chapman, 1987)	Existence of wars and disturbances
(Chopra and Sodhi, 2004); (Neuenkirch and Neumeier, 2015)	Sanctions
(Al-Marhubi, 2000); (Arip, Yee and Abdul Karim, 2010)	Reduce exports
(Akintoye and MacLeod, 1997)	Rising inflation
(Cooper and Chapman, 1987); (Tang and Musa, 2011)	Currency fluctuations in the country
(Chopra and Sodhi, 2004)	Business tax issues
(Tah, Thorpe and McCaffer, 1993); (Loayza, Ranciere, Servén and Ventura, 2007)	Existence of recession
(Arip *et al*., 2010); (Mohsin and Knight, 1988)	Increase imports
(Ravallion and Chen, 2007)	Increasing poverty
(Beasley and Danesi, 2010)	Lack of advertising in the product
(Bengtsson, Boter and Vanyushyn, 2007); (N Sheth and Sharma, 2005)	Not using e-marketing
(Perry and Grinaker, 1994)	Lack of research and development unit
(Sofyalıoğlu and Kartal, 2012); (Blackhurst, Scheibe and Johnson, 2008)	Law
(Sofyalıoğlu and Kartal, 2012)	Government and regulations
(Sofyalıoğlu and Kartal, 2012)	Natural disasters such as floods, earthquakes, fires
(Sofyalıoğlu and Kartal, 2012)	Lack of cooperation with unsuitable supplier
(Sofyalıoğlu and Kartal, 2012)	Transport capacity
(Sofyalıoğlu and Kartal, 2012)	Clearance of goods at customs and ports
(Sofyalıoğlu and Kartal, 2012)	Inadequate quality of service
(Sofyalıoğlu and Kartal, 2012)	Supplier obligations and inventory maintenance costs
(Sofyalıoğlu and Kartal, 2012)	Inadequate product quality
(Sofyalıoğlu and Kartal, 2012)	Increasing customer demand
(Sofyalıoğlu and Kartal, 2012)	Social insecurity
(Munro, Rodwell and Harding, 1998)	Job stress

To determine the most important risks of the 70 identified risks, 9 factors and 48 criteria of the risks were identified using the F Delphi technique and after 2 cycles of rotation. The content validity of this questionnaire was analyzed by 10 food industries experts. The identified factors and indices of risks are summarized in Table 6.

Risks of food supply chain in the industry units in Golestan province	**Internal factors of organizational supply chain**	**Suppliers (*C1*)**	*C14*	High cost of transportation
			C19	Inability to meet demands
			C111	Timely supply of raw materials
			C113	Increasing interest rates of banks and institutions
		Manufacturers (*C2*)	*C23*	Lack of production quality
			C24	Failure to send on time
			C27	Lack of liquidity
			C29	High level of competition
			C210	Liberalization of energy carrier prices
			C211	Wrong production schedule
			C212	Unhealthy competition
			C214	Rising cost of the product
			C216	Lack of experienced technical staff in the province
			C218	Stop production
		Distributors (*C3*)	*C32*	Incorrect demand forecast
			C36	Product return by the customer
			C37	Receive arrears
		consumers (*C4*)	*C41*	Increase the price of the final product
			C43	Decreased purchasing power of different segments of the population
			C44	Cultural differences
		Sanitation and Health (*C5*)	*C52*	Risk of respiration of chemical particles, dust and gases from machinery in the workplace
			C54	Stand for a long time
			C55	Carrying more than the load capacity by the worker
			C57	Use of stimulants and caffeine by the worker
			C510	Improper handling of cargo by the worker
			C511	Prolonged sitting and repetitive work
			C512	Existence of a lot of noise in the workplace
	External factors of organizational supply chain	**Biologically (*C6*)**	*C61*	Malta fever
			C63	Prevalence of Quaid disease 19
			C64	Smallpox
		Political (*C7*)	*C72*	Strikes
			C73	International relations of the country
			C75	Existence of lobbying in the field of production
			C76	Existence of wars and disturbances
			C79	Sanctions
		Economic (*C8*)	*C81*	Reduce exports
			C82	Rising inflation
			C83	Currency fluctuations in the country
			C85	Business tax issues
			C87	Existence of recession
			C88	Increase imports
			C810	Increasing poverty
		Technology (*C9*)	*C91*	Lack of advertising in the product
			C92	Not using e-marketing
			C93	Lack of research and development unit
		Environmental (*C10*)	*C101*	Law
			C102	Government and regulations
			C103	Natural disasters such as floods, earthquakes, fires

In the following, according to Table 6, the most important and the least important criteria were examined, and finally, among the risk factors, "economic factors (R8)" and "biological factors (R6)" were identified as the most important and least important factors, respectively. Moreover, among the criteria, R19 and R113 in the factor of suppliers; R29 and R216 in the factor of manufacturers; R37 and R32 in the factor of distributors; R44 and R43 in the factor of consumers; R54 and R511 in the factor of health; R63 and R61 in biological factors; R73 and R79 in the political factor; R81 and R85 in the factor of economic issues; R92 and R93 in the factor of technology; R101 and R103 in the environmental factor were identified as the most important and least important criteria, respectively.

4.2 Results of The F BWM

In this section, the preference vector of the most important factor and the most important criterion was determined. To determine this vector, the experts were asked to specify the most important factor and criterion. Then, the geometric mean of the collected data was calculated. Next, the preference vector of other factors and criteria was determined in relation to the least important factor and criterion. To determine this vector, the same procedures as the previous step were followed. Then, the optimal values of the weights were obtained. Weights for each factor and criterion were calculated by solving the linear model through LINGO 12.0 software. Eventually, the final weight of each criterion, according to the hierarchy of criteria, was obtained by multiplying the weight of each criterion by its factor. Table 7 shows these results.

Table 7. The final weights of the criteria in the risk failure structure

Factors	Factor weights	Criteria	Criteria weights	Final criteria weights
R_1	(0/0648,0/0835,0/1030)	R_{14}	(0/2427,0/2958,0/3480)	(0/0157,0/0247,0/0358)
		R_{19}	(0/1050,0/1052,0/1062)	(0/0068,0/0088,0/0109)
		R_{111}	(0/1791,0/2301,0/2849)	(0/0116,0/0192,0/0293)
		R_{113}	(0/3384,0/3883,0/4399)	(0/0219,0/0324,0/0453)
R_2	(0/0635,0/1037,0/1198)	R_{23}	(0/0881,0/1118,0/1279)	(0/0056,0/0116,0/0153)
		R_{24}	(0/0582,0/0686,0/0803)	(0/0037,0/0071,0/0096)
		R_{27}	(0/0972,0/1086,0/1331)	(0/0062,0/0113,0/0159)
		R_{29}	(0/0490,0/0497,0/0567)	(0/0031,0/0052,0/0068)
		R_{210}	(0/0670,0/0787,0/1063)	(0/0043,0/0082,0/0127)
		R_{211}	(0/0943,0/1200,0/1419)	(0/0060,0/0124,0/0170)
		R_{212}	(0/0773,0/0906,0/1021)	(0/0049,0/0094,0/0122)
		R_{214}	(0/0888,0/0989,0/1272)	(0/0056,0/0103,0/0152)
		R_{216}	(0/1823,0/1863,0/2154)	(0/0116,0/0193,0/0258)
		R_{218}	(0/0773,0/0951,0/1204)	(0/0049,0/0099,0/0144)
R_3	(0/0875,0/1087,0/1567)	R_{32}	(0/1320,0/1478,0/1519)	(0/0116,0/0161,0/0238)
		R_{36}	(0/2175,0/2678,0/3053)	(0/0190,0/0291,0/0478)
		R_{37}	(0/5550,0/6191,0/6200)	(0/0486,0/0673,0/0972)
R_4	(0/0894,0/0894,0/1387)	R_{41}	(0/2699,0/3357,0/3975)	(0/0241,0/0300,0/0551)
		R_{43}	(0/4746,0/5485,0/5814)	(0/0424,0/0490,0/0806)
		R_{44}	(0/1359,0/1448,0/1449)	(0/0121,0/0129,0/0201)
R_5	(0/0667,0/0948,0/1010)	R_{52}	(0/1371,0/1541,0/2202)	(0/0091,0/0146,0/0222)
		R_{54}	(0/0642,0/0646,0/0732)	(0/0043,0/0061,0/0074)
		R_{55}	(0/1218,0/1592,0/1724)	(0/0081,0/0151,0/0174)
		R_{57}	(0/1107,0/1217,0/1823)	(0/0074,0/0115,0/0184)
		R_{510}	(0/0813,0/0913,0/1235)	(0/0054,0/0087,0/0125)
		R_{511}	(0/2759,0/2760,0/3063)	(0/0184,0/0262,0/0309)
		R_{512}	(0/1141,0/1269,0/1659)	(0/0076,0/0120,0/0168)
R_6	(0/1880,0/1932,0/1933)	R_{61}	(0/1416,0/1600,0/1840)	(0/0266,0/0309,0/0356)
		R_{63}	(0/6237,0/6238,0/6239)	(0/1173,0/1205,0/1206)
		R_{64}	(0/1896,0/2336,0/2890)	(0/0356,0/0451,0/0559)
R_7	(0/0749,0/0968,0/0969)	R_{72}	(0/1628,0/1806,0/2398)	(0/0122,0/0175,0/0232)
		R_{73}	(0/0961,0/0962,0/1104)	(0/0072,0/0093,0/0107)
		R_{75}	(0/1440,0/1496,0/2147)	(0/0108,0/0145,0/0208)
		R_{76}	(0/1635,0/1862,0/2590)	(0/0122,0/0180,0/0251)
		R_{79}	(0/3727,0/3728,0/4207)	(0/0279,0/0361,0/0408)
R_8	(0/0449,0/0471,0/0486)	R_{81}	(0/0547,0/0643,0/0644)	(0/0025,0/0030,0/0031)

Factors	Factor weights	Criteria	Criteria weights	Final criteria weights
		R_{82}	(0/1465,0/1794,0/1796)	(0/0066,0/0084,0/0087)
		R_{83}	(0/1105,0/1415,0/1502)	(0/0050,0/0067,0/0073)
		R_{85}	(0/2071,0/2469,0/2470)	(0/0093,0/0116,0/0120)
		R_{87}	(0/1105,0/1427,0/1690)	(0/0050,0/0067,0/0082)
		R_{88}	(0/1072,0/1498,0/1551)	(0/0048,0/0071,0/0075)
		R_{810}	(0/1105,0/1140,0/1518)	(0/0050,0/0054,0/0074)
R_9	(0/0707,0/1235,0/1251)	R_{91}	(0/2807,0/3210,0/3978)	(0/0198,0/0396,0/0498)
		R_{92}	(0/1422,0/1423,0/1424)	(0/0101,0/0176,0/0178)
		R_{93}	(0/4799,0/5511,0/6222)	(0/0339,0/0681,0/0778)
R_{10}	(0/0702,0/0861,0/1079)	R_{101}	(0/1317,0/1411,0/1456)	(0/0092,0/0121,0/0157)
		R_{102}	(0/2430,0/3073,0/3791)	(0/0171,0/0265,0/0409)
		R_{103}	(0/5262,0/5803,0/5804)	(0/0369,0/0500,0/0626)

4.3 Calculating The Internal Relations of Criteria by F DEMATEL

At this stage, using the F DEMATEL method, the internal relationships among the criteria were identified and determined. Then, using the relationships among the criteria and the relationships of fuzzy ANP, the weight of the factors is calculated. For this purpose, firstly, the criteria were placed in a square pairwise comparison matrix. Then, using the experts' opinions and with the help of linguistic scales, which are as TFN, the criteria were scored. By gathering the experts' opinions, the fuzzy matrix related to the initial direct connection was created, and then, the total-relation fuzzy matrix was calculated. Finally, the causal diagram analysis was performed. All calculations were performed using MATLAB R2017a software. The results are shown in Table 8.

Table 8. The results of F DEMATEL

Criteria	F DEMATEL (R+C)
R_{14}	(0/77, 1/79, 3/89)
R_{19}	(2/2, 3/03, 5/12)
R_{111}	(1/13, 1/87, 3/95)
R_{113}	(1/09, 2/07, 4/19)
R_{23}	(2/04, 2/66, 4/83)
R_{24}	(1/01, 1/89, 3/92)
R_{27}	(1/27, 2/15, 4/29)
R_{29}	(2/37, 3/009, 5/15)
R_{210}	(0/64, 1/65, 3/73)
R_{211}	(1/37, 2/28, 4/41)
R_{212}	(0/99, 1/97, 4/11)
R_{214}	(1/44, 2/31, 4/42)
R_{216}	(0/42, 1/42, 3/51)
R_{218}	(1/78, 2/55, 4/61)
R_{32}	(0/85, 1/81, 3/91)
R_{36}	(0/58, 1/56, 3/65)
R_{37}	(0/61, 1/57, 3/66)
R_{41}	(0/26, 1/34, 3/41)
R_{43}	(1/49, 2/81, 4/48)
R_{44}	(1/39, 2/72, 4/49)
R_{52}	(0/29, 1/29, 3/42)
R_{54}	(0/31, 1/35, 3/42)
R_{55}	(0/22, 1/26, 3/31)
R_{57}	(0/52, 1/54, 3/64)
R_{510}	(0/14, 1/25, 3/29)
R_{511}	(0/21, 1/24, 3/32)
R_{512}	(0/082, 1/1, 3/13)
R_{61}	(0/78, 1/76, 3/86)
R_{63}	(0/32, 1/37, 3/46)
R_{64}	(0/24, 1/31, 3/39)

Criteria	F DEMATEL (R+C)
R_{72}	(0/64, 1/69, 3/79)
R_{73}	(1/97, 3/45, 4/86)
R_{75}	(0/54, 1/54, 3/64)
R_{76}	(0/63, 1/63, 3/72)
R_{79}	(0/53, 1/49, 3/62)
R_{81}	(1/74, 2/49, 4/53)
R_{82}	(1/71, 2/51, 4/67)
R_{83}	(1/91, 2/69, 4/82)
R_{85}	(0/99, 1/93, 4/04)
R_{87}	(1/87, 2/61, 4/74)
R_{88}	(0/94, 1/83, 3/92)
R_{810}	(1/2, 2/43, 4/24)
R_{91}	(0/48, 1/48, 3/58)
R_{92}	(0/59, 1/57, 3/68)
R_{93}	(0/52, 1/48, 3/61)
R_{101}	(1/46, 2/63, 4/39)
R_{102}	(0/12, 1/23, 3/31)
R_{103}	(0/22, 1/28, 3/35)

4.4 The Final Weight of The Criteria From The Combination of F BWM and F DEMATEL

In this step, the final weight of the criteria is obtained by multiplying the weight of the criteria of F BWM by the weight of the criteria of the F DEMATEL method. It is noteworthy that at first, the values are normalized, and then, the resulting values are defuzzified and finally prioritized. In other words, first, the data values are normalized using a linear method, and then they are defuzzified via the center of gravity method according to Equation (2). As an example, for criterion R14 of Table 9, the hybrid weight (0/0121, 0/0442, 0/1393) is obtained from the product of values of the second and third columns. In continuing, this hybrid weight is linearized after normalizing its value as (0/02362, 0/02480, 0/02691). Now, the defuzzified value of weight corresponding to criterion R14 by applying Equation (2) is calculated as follows:

$$\frac{0.02362 + 4 * 0.02480 + 0.02691}{6} = 0.025$$

The results calculated in this step are presented in Table 9.

Table 9. Final weights of indices

Criteria	Weights obtained by F BWM	Weights obtained by DEMATEL	Hybrid weights obtained by F DEMATEL and F BWM	Defuzzified	Rank
R_{14}	(0/0157,0/0247,0/0358)	(0/77, 1/79, 3/89)	(0/0121, 0/0442, 0/1393)	0/0250	12
R_{19}	(0/0068,0/0088,0/0109)	(2/2, 3/03, 5/12)	(0/0150, 0/0267, 0/0558)	0/0166	22
R_{111}	(0/0116,0/0192,0/0293)	(1/13, 1/87, 3/95)	(0/0131, 0/0359, 0/1157)	0/0214	15
R_{113}	(0/0219,0/0324,0/0453)	(1/09, 2/07, 4/19)	(0/0239,0/0671,0/1898)	0/0390	5
R_{23}	(0/0056,0/0116,0/0153)	(2/04, 2/66, 4/83)	(0/0114, 0/0309, 0/0739)	0/0176	18
R_{24}	(0/0037,0/0071,0/0096)	(1/01, 1/89, 3/92)	(0/0037, 0/0134, 0/0376)	0/0074	43
R_{27}	(0/0062,0/0113,0/0159)	(1/27, 2/15, 4/29)	(0/0157,0/0247,0/0358)	0/0139	29
R_{29}	(0/0031,0/0052,0/0068)	(2/37, 3/009, 5/15)	(0/0073, 0/0156, 0/0350)	0/0094	40
R_{210}	(0/0043,0/0082,0/0127)	(0/64, 1/65, 3/73)	(0/0028, 0/0135, 0/0474)	0/0075	42
R_{211}	(0/0060,0/0124,0/0170)	(1/37, 2/28, 4/41)	(0/0082, 0/0283, 0/0750)	0/0157	25
R_{212}	(0/0049,0/0094,0/0122)	(0/99, 1/97, 4/11)	(0/0049, 0/0185, 0/0501)	0/0101	37
R_{214}	(0/0056,0/0103,0/0152)	(1/44, 2/31, 4/42)	(0/0081, 0/0238, 0/0672)	0/0137	30
R_{216}	(0/0116,0/0193,0/0258)	(0/42, 1/42, 3/51)	(0/0049, 0/0274, 0/0906)	0/0148	26
R_{218}	(0/0049,0/0099,0/0144)	(1/78, 2/55, 4/61)	(0/0087, 0/0252, 0/0664)	0/0144	27
R_{32}	(0/0116,0/0161,0/0238)	(0/85, 1/81, 3/91)	(0/0099, 0/0291, 0/0931)	0/0171	20
R_{36}	(0/0190,0/0291,0/0478)	(0/58, 1/56, 3/65)	(0/0110, 0/0454, 0/1745)	0/0262	11

Criteria	Weights obtained by F BWM	Weights obtained by DEMATEL	Hybrid weights obtained by F DEMATEL and F BWM	Defuzzified	Rank
R_{37}	(0/0486,0/0673,0/0972)	(0/61, 1/57, 3/66)	(0/0296, 0/1057, 0/3558)	0/0606	3
R_{41}	(0/0241,0/0300,0/0551)	(0/26, 1/34, 3/41)	(0/0063, 0/0402, 0/1879)	0/0231	13
R_{43}	(0/0424,0/0490,0/0806)	(1/49, 2/81, 4/48)	(0/0632, 0/1377, 0/3611)	0/0837	2
R_{44}	(0/0121,0/0129,0/0201)	(1/39, 2/72, 4/49)	(0/0168, 0/0354, 0/0902)	0/0216	14
R_{52}	(0/0091,0/0146,0/0222)	(0/29, 1/29, 3/42)	(0/0026, 0/0188, 0/0759)	0/0103	36
R_{54}	(0/0043,0/0061,0/0074)	(0/31, 1/35, 3/42)	(0/0013, 0/0082, 0/0253)	0/0043	48
R_{55}	(0/0081,0/0151,0/0174)	(0/22, 1/26, 3/31)	(0/0018, 0/0190, 0/0576)	0/0095	39
R_{57}	(0/0074,0/0115,0/0184)	(0/52, 1/54, 3/64)	(0/0038, 0/0177, 0/0670)	0/0100	38
R_{510}	(0/0054,0/0087,0/0125)	(0/14, 1/25, 3/29)	(0/0008, 0/0109, 0/0411)	0/0056	46
R_{511}	(0/0184,0/0262,0/0309)	(0/21, 1/24, 3/32)	(0/0039, 0/0325, 0/1026)	0/0167	21
R_{512}	(0/0076,0/0120,0/0168)	(0/082, 1/1, 3/13)	(0/0006, 0/0132, 0/0526)	0/0068	45
R_{61}	(0/0266,0/0309,0/0356)	(0/78, 1/76, 3/86)	(0/0207, 0/0544, 0/1374)	0/0315	7
R_{63}	(0/1173,0/1205,0/1206)	(0/32, 1/37, 3/46)	(0/0375, 0/1651, 0/4173)	0/0874	1
R_{64}	(0/0356,0/0451,0/0559)	(0/24, 1/31, 3/39)	(0/0085, 0/0591, 0/1895)	0/0310	8
R_{72}	(0/0122,0/0175,0/0232)	(0/64, 1/69, 3/79)	(0/0078, 0/0296, 0/0879)	0/0164	24
R_{73}	(0/0072,0/0093,0/0107)	(1/97, 3/45, 4/86)	(0/0142, 0/0321, 0/0520)	0/0183	17
R_{75}	(0/0108,0/0145,0/0208)	(0/54, 1/54, 3/64)	(0/0058, 0/0223, 0/0757)	0/0127	33
R_{76}	(0/0122,0/0180,0/0251)	(0/63, 1/63, 3/72)	(0/0077, 0/0293, 0/0934)	0/0165	23
R_{79}	(0/0279,0/0361,0/0408)	(0/53, 1/49, 3/62)	(0/0148, 0/0538, 0/1477)	0/0297	10
R_{81}	(0/0025,0/0030,0/0031)	(1/74, 2/49, 4/53)	(0/0044, 0/0075, 0/0140)	0/0047	47
R_{82}	(0/0066,0/0084,0/0087)	(1/71, 2/51, 4/67)	(0/0113, 0/0213, 0/0406)	0/0130	31
R_{83}	(0/0050,0/0067,0/0073)	(1/91, 2/69, 4/82)	(0/0096, 0/0180, 0/0352)	0/0110	34
R_{85}	(0/0093,0/0116,0/0120)	(0/99, 1/93, 4/04)	(0/0092, 0/0224, 0/0485)	0/0129	32
R_{87}	(0/0050,0/0067,0/0082)	(1/87, 2/61, 4/74)	(0/0094, 0/0175, 0/0389)	0/0108	35
R_{88}	(0/0048,0/0071,0/0075)	(0/94, 1/83, 3/92)	(0/0045, 0/0130, 0/0294)	0/0073	44
R_{810}	(0/0050,0/0054,0/0074)	(1/2, 2/43, 4/24)	(0/0060, 0/0131, 0/0314)	0/0079	41
R_{91}	(0/0198,0/0396,0/0498)	(0/48, 1/48, 3/58)	(0/0096, 0/0586, 0/1783)	0/0308	9
R_{92}	(0/0101,0/0176,0/0178)	(0/59, 1/57, 3/68)	(0/0060, 0/0276, 0/0655)	0/0143	28
R_{93}	(0/0339,0/0681,0/0778)	(0/52, 1/48, 3/61)	(0/0176, 0/1008, 0/2809)	0/0525	4
R_{101}	(0/0092,0/0121,0/0157)	(1/46, 2/63, 4/39)	(0/0136, 0/0321, 0/0689)	0/0186	16
R_{102}	(0/0171,0/0265,0/0409)	(0/12, 1/23, 3/31)	(0/0021, 0/0326, 0/1354)	0/0172	19
R_{103}	(0/0369,0/0500,0/0626)	(0/22, 1/28, 3/35)	(0/0081, 0/0640, 0/2097)	0/0333	6

According to the solution of the linear programming model of F BWM and its combination with the F DEMATEL method, it is observed that among the 48 criteria, the criteria of the COVID-19 pandemic with identification code of R63, the reduced purchasing power of people with the identification code of R43, receiving arrears with identification code of R37, and the lack of RandD units with identification code of R93, respectively, have the highest risks in the industrial units. In Table 10, the definitions and more details related to these risks are briefly presented.

Table 10. Definitions related to higher priority risks

Risk	Identification Code	Definition and detail
COVID-19 pandemic	R63	The infectious disease covid-19 has a dangerous impact on the health supply chain. The effects of this risk in the supply chain may be as follows: the effect on the presence and absence of workers, the effect on productivity, changes in policies and regulations, and economic effects.
Reduced purchasing power of people	R43	The decrease in the purchasing power of people in the production supply chain refers to the decrease in the purchasing power of customers and consumers in the market. This risk may arise from various factors that are related to changes in economic, social, or cultural conditions. A drop in purchasing power can have

Risk	Identification Code	Definition and detail
		direct and indirect effects on the supply and production chain. Some of the factors and effects related to this risk include decrease in demand, pressure on prices, changes in consumption patterns and impact on marketing and brand.
Receiving arrears	R37	The risk of receiving arrears in the production supply chain means facing delays or problems in receiving payments or financial arrears among members of the supply chain. This problem may arise at any stage of the supply chain, from the main suppliers to the end customers. The risk of receiving arrears can lead to financial arrears, delays in processes, or even direct effects on the liquidity and financial stability of the business.
Lack of RandD units	R93	The risk associated with the lack of research and development units in the production supply chain refers to possible problems and losses that are caused by the lack or absence of research and development activities in the production processes and activities of an organization. Some of these risks are mentioned below: lack of innovation, reduction of product quality, failure to predict market changes and loss of brand reputation.
Increase in the interest rates of banks and institutions	R113	Bank rate risk is an important factor in the production chain that can have a direct impact on costs and productivity throughout the chain. This risk is often referred to as "interest rate risk". Some of the factors related to this risk are: increase in financing cost, increase in production cost, decrease in business efficiency, etc.

5. MANAGERIAL CONSEQUENCES

The purpose of applying the risk assessment and prioritization in organizations is to examine the potential consequences of probable accidents on people, materials, equipment and the environment. In fact, it determines the efficacy of existing control methods and provides valuable data for decision-making to reduce risks and to improve control systems and plans for reacting to them, which can save or reduce the organization's financial and human costs before the accident happens. In this study, the five main factors of the COVID-19 pandemic, the decrease in the purchasing power of different segments of the population, receiving arrears, the lack of RandD units, increase in the interest rates of banks and institutions, respectively, have the highest risks for food industry units in Golestan province, Iran.

6. CONCLUSION

Risk assessment has become a key issue in the supply chain and plays an important role in chain performance and continuity of organizational dynamics. It is worth noting that the specialized analysis of internal and external organizational risks, as well as considering their internal relationships and structures, along with the interaction among them, have been neglected in FSCs so far. In addition, it is not only necessary to identify these risks, but they also need to be prioritized so that managers can face fewer challenges by recognizing and managing them properly.

Considering the importance of manufacturing risks in HSC and the lack of a comprehensive model in the field of risk prediction, this paper tried to identify the risks in the supply chain of the food industry units of Golestan province, Iran. For this purpose, a hybrid model based on fuzzy logic methodology, F Delphi, F BWM and F DEMATEL, was proposed. By using fuzzy concepts, decision-makers will be able to use verbal expressions as linguistic variables and apply more appropriate and accurate analyses to the topic of this study. In the first step, all the potential risks are recognized utilizing the field and library research methods, and then, by using the F Delphi technique, the final risks are determined. In the second step, the weights corresponding to these risks are calculated by F BWM, and the internal relationships among the risks are determined by employing the F DEMATEL technique. In the following, by combining the F BWM and F DEMATEL methods, the final weights are calculated, and next, the identified risks are ranked. The proposed approach has several advantages. Food industry units can identify the main risks and sub-criteria and examine how they affect these units without considering the interdependencies among the criteria. Using the F DEMATEL approach, direct and indirect effects will be applied to understand the causal relationships among the criteria. This can lead to better and more accurate performance for risk reduction. In addition, the correlations among the criteria are considered as the importance weights in the comparison process. The results of the research indicate that the five main factors of the COVID-19 pandemic, the decrease in the purchasing power of different segments of the population, receiving arrears, the lack of RandD units, increase in the interest rates of banks and institutions, respectively, have the highest risks for food industry units in Golestan province, Iran.

For future research, interested researchers can carry out some other related studies as follows:

- Researchers can use other weighting techniques such as fuzzy linear goal programming, logarithmic fuzzy preference programming, and ranking methods such as MACONT, FUCOM, and COCOSO.
- To identify risks, researchers can employ other methods such as the analogical approaches, the heuristic approaches, and the analytical approaches.
- As the number of criteria increases, the amounts of calculations increases and therefore, providing a metaheuristic method in future research can be worthwhile to reduce the amounts of calculations.
- Providing an appropriate model for evaluating and selecting response measures to risks is also suggested for further research.

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